Dairy Plant Water Conservation by CIP System Redesign and Loadout of Cow Drinkable High BOD Water

Emmy Schroder, Amanda Peterson, Anna Ameser
The Ohio State University College of Engineering

ABSTRACT

Snowville Creamery is a sustainable dairy processing plant which prides itself on providing dairy products that are as close to natural as possible. As production quantities grow, so does the plant's water usage and waste. All drained wastewater is spray irrigated to the pastures, and since the farm raises exclusively grass fed cattle, it is essential to minimize the quantity of the wastewater as well as its biological oxygen demand (BOD) and concentration of suspended solids. Previously, all cleaning processes utilized fresh city water with no reuse. The goal of this study was to discover and implement methods of water reuse and repurposing for dairy plants. By benchmarking water usage at various points, it was possible to quantify and analyze required water volumes in each process. First, a recirculation system was established for the milk separator. Additionally, a high BOD segregation collection system was designed to capture the established "Clean in Place" (CIP) pre-rinse water, as well as usable water from the pasteurizer and Nanofiltration CIP systems to be used as a nutritious drinking source for the cows. The remaining CIP steps were also redesigned to reduce water usage from 8 to 3.4 times the circuit volume of a given processing component. The total projected water savings from all sources are 23,500 gallons per week for a savings of $8,070 per year. Along with the implementation and programming of these systems with PLC automation, full AutoCAD documentation of the Creamery P&ID and schematic was designed and updated. These water conservation methods can be applied to other dairy or food processing plants for water conservation and savings.

BACKGROUND

Snowville Creamery, the industry sponsor for this Research Project, is led and advised by Warren Taylor, owner and CEO. The Creamery has 5.5 million dollars worth of sales every year, using 750,000 lbs. of raw milk per month. The main goal of this project is to reduce the volume of waste water that is disposed of on a daily basis by 50%, while reducing BOD and suspended solids. The plant's spray irrigation treatment method makes it important to keep volume low and quality high. By measuring and analyzing sources of current water usage, the team was able to develop a cost effective improvement plan for the Creamery to implement. Figure 1 shows the water usage data from over a month separated into average drained water per type of production day: milk, ice cream, or yogurt per source. Figure 2 shows the Creamery layout at the beginning of the project.

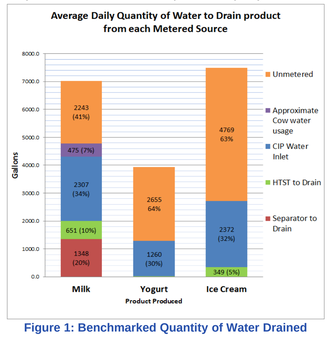

Figure 1: Benchmarked Quantity of Water Drained

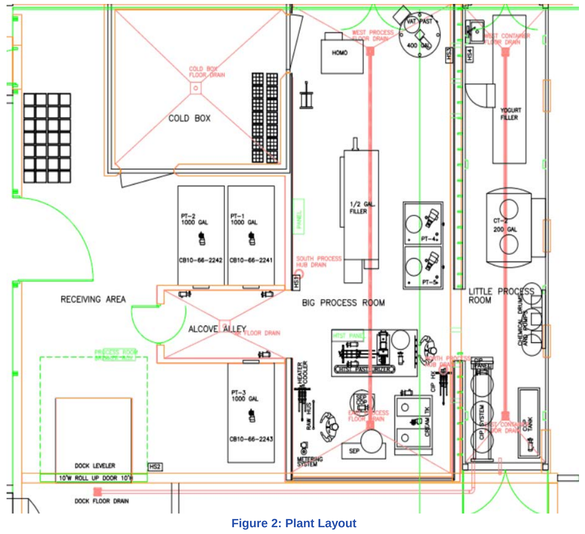

Figure 2: Plant Layout

REFERENCES/ ACKNOWLEDGEMENTS

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HIGH BOD SEGREGATION METHODS

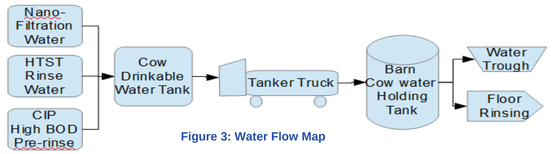

Figure 3: Water Flow Map

CIP PROCESS ALTERATIONS

About 30% of the daily water use was for the CIP (Clean in Place) system. The original CIP process had six steps and utilized 8 times the circuit volume of water. This process was redesigned with two new CIP rinse solution recovery tanks for each subsequent flush. Figure 4 and Table 1 show the new CIP flush steps with colors corresponding to the sequence and flow of reused water.

Table 1: Improved CIP Process

Step	From	To	Circuit Volume	
			Recovered Reused Solution	Fresh Water
1) BOD Flush	Fresh water	Cow Drinkable Water Tank	--	1.0x
2) Prerinse	Caustic post Rinse Recovery Tank	Drain (Neutralization Tank)	2.0x	--
3) Caustic Wash	Caustic Wash Tank	Caustic Wash Tank	--	0.2x (average)
4) Caustic Post Rinse	Acid Post Rinse Recovery Tank	Caustic Post Rinse Recovery Tank	2.0x	--
5) Acid wash	Acid Wash Tank	Acid Wash Tank	--	0.2x (average)
6) Acid Post Rinse	Acid Sanitizer Tank +1.0 fresh water	Acid Post Rinse Recovery Tank	1.0x	1.0x
7) Acid Sanitizer	Fresh water	Acid Sanitizer Tank	--	1.0x
	Total Fresh Water Volume			**3.4x circuit volume**

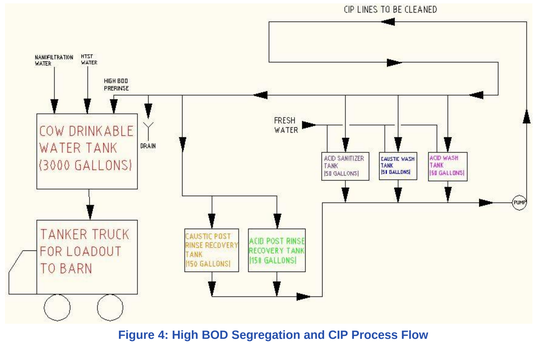

Figure 4: High BOD Segregation and CIP Process Flow

Figure 5: The Path of One Batch of Cleaning Water

Figure 5 shows the reuse path of one "batch" of cleaning water, being used to flush the system three separate times before being discarded to the drain for irrigation. Once the PLC programming is complete, and the first flush is segregated for high BOD cow consumption, the water usage is projected in Table 2 below.

Table 2: Current and Projected CIP System Water Usage and Diversion for Cow Water

Production Day	Pre- Project CIP average water usage (gallons)	Projected CIP water usage (gallons)	Projected High BOD Waste Collection amount for cows (gallons)
Milk	2,307	750	163
Yogurt	1,260	420	6
Ice Cream	2,372	791	87
Weekly Total	12,239	3,978	675

High BOD waste water that is safe for cow consumption will be segregated out from the CIP (Clean in Place) pre-rinse, pasteurizer CIP rinses, and the Nanofiltration system CIP, along with the Nanofiltration system byproduct. The PLC automated 'cow drinkable water tank' will be emptied into a tanker truck daily for transport of up to 2,650 gallons of water to the barn. Based on current projections, the maximum daily quantity that will need to be transported is about 1,800 gallons. Figure 3 shows a simplified flow map of this process.

HTST PASTEURIZER SEGREGATION

Figure 6: HTST Pasteurizer

The high temperature short time (HTST) pasteurizer, shown in Figure 6, utilizes a separate CIP system. The CIP rinses, which are not contaminated with chemicals, will be diverted to the cow drinkable water tank. The HTST CIP system is currently utilizing 2,464 gallons of water per week. It is projected that the CIP water usage to drain for irrigation can be reduced by 20%, or 493 gallons as shown in Table 3.

Table 3: Projected HTST Pasteurizer High BOD segregation

Production Day	Pre- Project HTST average water to drain (gallons)	Projected HTST water to drain (80%)	Projected High BOD Waste Collection amount for cows (20%)
Milk	650	520	130
Yogurt	22	18	4
Ice Cream	349	279	70
Weekly Total	2,464	1,972	493

NANOFILTRATION SEGREGATION

The Nanofiltration system (Figure 7) squeezes excess water from the milk to be used for ice cream mix. The Nanofiltration system also utilizes a separate CIP system. Automated valves will be installed and programmed to divert the 40% of the Nano-CIP water that is projected to be cow drinkable, as well as the extracted water, to the tanker. This equates to a weekly savings of 5,758 gallons per week as in Table 4.

Figure 7: Nanofiltration System

Table 4: Nanofiltration System Segregation Projections

Production Day	Current Unmetered water usage (gallons)	Estimated gallons of unmetered that is Nanofiltration CIP usage (75% of unmetered)	Estimated gallons of nano-CIP usage that is Projected to be able to collect for cows (40% of nano CIP)
Milk	2,243	1,682	673
Yogurt	2,655	1,991	797
Ice Cream	4,769	3,577	1,430
Weekly Total	19,193	14,395	5,758

SEPARATOR RECIRCULATION

Figure 8 shows the Separator which splits the cream from the milk. To eliminate the majority of the water wasted during start-up and shutdown, a recirculation loop utilizing several automated valves was installed. Savings are shown in Table 5. This allows the system to recirculate water until the separator is up to speed and ready to run milk. The valve that loops the water back into the raw milk input stream is shown in Figure 9, and the entire setup is shown in the Results section in Figure 13.

Figure 8: Raw Milk Separator

Figure 9: Separator Recirculation Valve and Pump

Table 5: Current and Projected Separator water usage

Production Day	Pre- Project Separator average water usage (gallons)	Projected Separator water usage (gallons)
Milk	1347	82
Yogurt	0	0
Ice Cream	0	0
Weekly Total	3,818	246

PROJECTED GAINS/ DISCUSSION

Water usage metered data was collected for two months. Analyzing the data based on product production day, forecasts were made for the system as a whole regarding water usage and high BOD diversion as shown in Figure 10 and Figure 11.

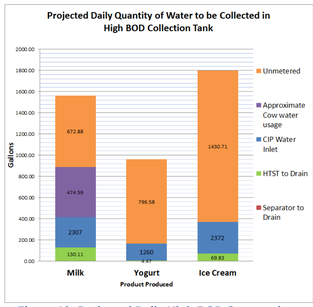

Figure 10: Projected Daily High BOD Segregation

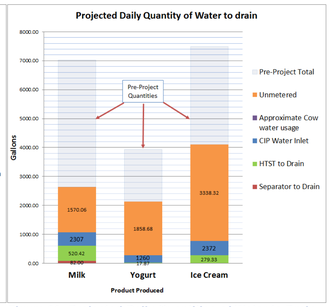

Figure 11: Projected Daily Quantities of Water to Drain

High BOD tank validation

- Input sources (960-1800 gal/day): Nanofiltration cow water and CIP, HTST, CIP flush
- <3000 gal capacity of tank
- The 250 cows can consume 5,000 gallons/day

Net water savings:

- Separator recirculation piping = 1278 gal/day
- CIP system reusages (reduced from 8 x to 3.4 x the circuit volume) = 1305 gal/day
- Unmetered Nano: 30% diversion
- HTST: 15% BOD diversion

Table 6 below shows an overview of the total forecasted reductions in water usage, resulting in a 54% reduction.

Table 6: Reduction in Water Sent to the Drain on a Daily and Weekly Basis

Production Day	Pre- Project Water Usage/ drained Averages (Gallons)	Projected Water to Drain (Gallons)	% Reduction in Water sent to the Drain
Milk	7,023	2,637	62%
Yogurt	3,937	2,137	46%
Ice Cream	7,490	4,108	45%
Weekly Average	43,924	20,401	54%

OVERVIEW AND CONCLUSION

Figure 12 displays the new AutoCAD work completed on the P&ID of the CIP system. It shows the addition of the two reuse tanks, and the path of the new segregation system for the cow drinkable water. These improvements will save water in the creamery, while providing high nutrient water to the grass grazed cows in the barn. Figure 13 shows the updated AutoCAD drawing of the separator recirculation loop. The methods used in this project for water savings and sustainability can be translated into other dairy facilities for a similar benefit.

Overall water savings = 23,500 gallons per week ⇨ $8,070/year

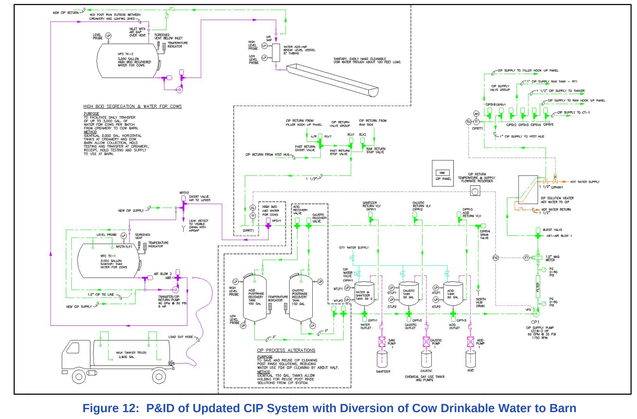

Figure 12: P&ID of Updated CIP System with Diversion of Cow Drinkable Water to Barn

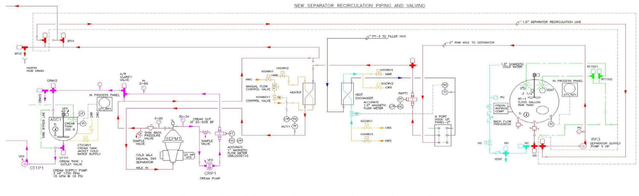

Figure 13: P&ID of Separator Recirculation System